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DEVELOPMENT OF PROBLEM SOLVING ABILITY AND LEARNING OF RELEVANT-IRRELEVANT INFORMATION THROUGH FILM AND TV VERSIONS OF A STRENGTH OF MATERIALS TESTING LABORATORY, FINAL REPORT.

BY- HARRIS, CHARLES O. AND OTHERS
MICHIGAN ST. UNIV., EAST LANSING.COLL. OF EDUC.

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SEVERAL PROBLEMS WHICH ARISE WITH THE USE OF FILM AND TELEVISION IN INSTRUCTION WERE INVESTIGATED. STUDY CONSIDERATIONS WERE FOCUSED ON DIFFERENTIATION BETWEEN RELEVANT AND IRREVELANT LEARNING BY COMPARING LABORATORY TEACHING TECHNIQUES FOR AN ENGINEERING COURSE WITH FILM PRESENTATIONS OF THE SAME MATERIAL. THERE WERE NO OVERALL SIGNIFICANT DIFFERENCES ATTRIBUTABLE TO THE FILM VERSUS LABORATORY METHODS OF PRESENTATION. FOR CERTAIN EXPERIMENTS, HOWEVER, THE FILM HAD DIFFERENTIAL EFFECTS. IN PROBLEM-SOLVING EXPERIMENTS, THREE METHODS WERE STUDIED--FILM ONLY, LABORATORY ONLY, AND FILM PLUS LABORATORY. THE COMBINED FILM AND LABORATORY METHOD WAS SIGNIFICANTLY MORE EFFECTIVE IN PREPARING THE STUDENT FOR APPLYING THEORY, METHODS, AND KNOWLEDGE ABOUT APPARATUS WHICH WERE LEARNED IN CLASS TO NEW PROBLEM SITUATIONS. INSTRUCTORS OF THE STRENGTH OF MATERIALS COURSE INVESTIGATED AGREED THAT FILMS CAN PRESENT, IN A SHORT PERIOD OF TIME, A SYSTEMATIC AND COMPLETE PRESENTATION WHICH IS DIFFICULT OT OBTAIN IN A LIVE PRESENTATION IN A LABORATORY. (JC)

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DEVELOPMENT OF PROBLEM SOLVING ABILITY AND LEARNING OF RELEVANT-IRRELEVANT INFORMATION THROUGH FILM AND TV VERSIONS OF A STRENGTH OF MATERIALS TESTING LABORATORY, FINAL REPORT

prepared by
Charles O. Harris
Paul J. Deutschmann
Ralph L. Vanderslice
Malcolm S. MacLean, Jr.
Anita M. McMillan
Lionel C. Barrow
Mary Anne Carmichael
Elke Koch-Weser

Division of Engineering Research
College of Engineering
MICHIGAN STATE UNIVERSITY
East Lansing, Michigan
November 5, 1962

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ABSTRACT

This research project was developed to investigate several problems which arise with the use of the new media of films and television in teaching situations. The considerations of this study have been focused on what can be learned. One of the major findings dealt with the differentiation between relevant and irrelevant learning by comparing laboratory teaching techniques with film presentations of the same material with regard to learning of relevant information. There was no significant overall difference attributable to the film versus the laboratory methods of presentation. However, for certain experiments the film had differential effects. As expected there was no significant difference in the learning of irrelevant material.

Another major concern of this project dealt with problem solving; that is, the presentation of new problems to the students which could be solved by extrapolating from the regular laboratory material. Three methods of presentation were studied: film only, laboratory only, and film plus laboratory. There was no difference between the film only and laboratory only methods. The combined film and laboratory method did differ from the other two in being more effective in preparing the student for applying the theory, methods, and knowledge about apparatus which were learned in class to new problem situations. The difference favoring the combined film and laboratory method was even more significant when the students' "general ability to handle the coursework" was controlled.

Overall, it has been agreed upon by the instructors of the Strength of Materials course that the films can present, in a concise period of time, a systematic and complete presentation which is difficult to obtain in a natural laboratory situation. In films, every student is given the opportunity to see and learn from every step of the experiment. In the natural laboratory, each student or group of students perform different tasks and are seldom able to benefit from the others' work.

Clearly, the most efficient method of presentation appears to be the combined film and laboratory, which enables the student to benefit from the expert presentation of the experiment, from first-hand knowledge of the apparatus available to him and from the actual conducting of the experiment. These films have shown to be as effective as the natural laboatory in terms of the relation of relevant and irrelevant learning and the preparation for problem solving tasks. In addition,

once the films are produced, it is economical to obtain prints to be used both in institutions with laboratory facilities and those which cannot financially make them available to students.

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1. INTRODUCTION

The general purpose of the research program was to compare student achievement in the traditional laboratory environment with those of three teaching patterns making use of the films. These three patterns were closed-circuit television (TV); Film only; and Film in conjunction with a laboratory (Laboratory plus Film).

Considerable work has been done to demonstrate that many teaching tasks can be successfully accomplished with the use of films. However, relatively little work has been done beyond the testing of dependent variables such as immediate learning using objective paper-and-pencil tests. Particularly, the ability after instruction to handle problems of the general class related to the content studied, has not often been investigated when the content was presented through one of the new media. Ability to solve similar but new problems, as well as to "possess" knowledge is particularly important for a subject matter such as strength of materials.

There is not much difficulty in applying the Shannon-Weaver model of the communication process to the classroom or laboratory situation. At least by analogy, similar concepts can quickly be found.

The teacher is the communicator-encoder. The student the decoder-receiver. The total complex of stimulation available to the receivers is the message plus noise. The part of the stimulation, including lecture, audio-visual *materials*, writing upon the blackboard, and discussion which is relevant to the purposes of the instructor is message. That part of the stimulation which is irrelevant is noise. This will include literal noise within and without the classroom, the idiosyncratic movements, mannerisms or dress of the instructor, left-over writings on the blackboard from earlier classes, the movements and appearances of other students, etc. *

The communicator, being less than a perfect encoder, may also have some irrelevancies intermingled in his lecture or audio-visual aids, i.e. there may be some parts of this stimulation which appear to be message which are in fact irrelevant to his purpose, and in this sense noise.

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* The classroom "noise" is, of course, not strictly random as in Information Theory noise. However, the very lack of randomness -- or degree of organization -- makes it potential interference capability greater.

It seems a fair assumption that the receivers in this situation have a channel capacity less than sufficient to decode the total stimulus situation. This can be tested indirectly if desired, by discovering the receiver's ability to reproduce the message plus noise. Ordinarily, he can reproduce some portion of the total stimulation, but not all. Perhaps the analogy is incomplete, but the receiver behaves as though he had a channel with a limited capacity.

At this point a dissimilarity between the Shannon model and the classroom situation maybe noted. In the neat Information Theory diagram, the communicator and receiver are linked (or coupled as Shannon puts it). A frequent image is of a telegraph operator linked by wire to a receiver operator.

Probably a better image of the student as a receiver is of a device which has to be focused to maintain the coupling. For example, one can think of a micro-wave beam being sent to a receiving apparatus which moves somewhat erratically. Now it is focused, now it is not. The student-receiver is more like this than like the telegraph receiver-operator. Now he attends, now he does not. And his ability to focus is considerably more complex than that of a receiver which can simply move in space, now fixing, now missing a focused beam. A whole literature on the selectivity of perception of human beings testified to this.

Thus there is something of a contest between the teacher-communicator and the student-receiver. The teacher attempts continually to maintain the coupling. He does this by the organization of his materials, and by trying to stop irrelevant discussion. The classroom itself is a type of focusing device, with the arrangement of seats working toward the maintenance of coupling.

It seems clear that any device which can increase the focus upon the relevant message and limit attention to the ever-present irrelevant noise should facilitate communication. In particular, in view of the assumed limited channel capacity, it would appear that if capacity is used up -- as it were -- upon decoding irrelevancies, it will not be available for relevant materials. **

** An alternate formulation might be based upon what is known about association. This would suggest that the more associations the receiver takes away from a stimulus situation, including both relevancies and irrelevancies, the better his chance of recalling any given part of the stimulus situation.

In testing for communication effectiveness, evidence is ordinarily sought to show that the relevancies (the message) have been decoded. A test of learning is such evidence. A test for the learning of irrelevancies is not made. On the face of it, such a procedure seems quite absurd. What difference does it make if the student-receiver is learning (decoding) some irrelevant material?

On the other hand, if the assumption about channel capacity is correct, the learning of irrelevancies might be quite important. It would indicate that the channel capacity of receivers in a given communication situation is being used up in an inefficient way -- at least from the point of view of the communicator-teacher.

An additional point arises; viz, there well may be differences between teaching methods (conceived as different communication situations) in terms of their ability to maintain a focus or coupling with student receivers. If there were such differences, it would be expected that differences between relative amounts of relevant and irrelevant materials which were learned (or decoded), would be found.

1.1. Teaching by Film or TV versus Classroom or Laboratory

If teaching by film or television versus teaching by classroom or laboratory in this light is viewed in this light, some differences are apparent. The film or TV situation may very well inherently screen out some of the irrelevancies which are present in the natural situation. Or if it does not screen them out entirely, it may reduce their intensity.

For example, TV reproduction of a stimulus situation -- classroom or laboratory -- will always lose some small amount of detail which is present in the original situation. In many instances this fine detail which is lost is part of the irrelevancies which are available in the natural situation. Film also is a means of focusing and/or reducing the intensity of irrelevancies. If a film version is shorter than a natural version, for example, the amount of irrelevant stimulation available will be reduced. This should be true of the normal classroom situation, but even more true of a laboratory, which seems manifestly richer in total stimulation for the student and particularly in irrelevant stimulation.

These differences from one condition to another are not necessarily large. Rather, they are customarily quite small.

It is argued that testing of the relevant material alone, the customary pattern in studies of various modes of classroom communication, minimizes the opportunity for discovering the relationship between relevant and irrelevant learning (decoding). On the other hand, if tests are conducted

for both kinds of learning, our chances of discerning the difference which may exist should be improved.

Manifestly, the testing involved in this study cannot cover the total range of stimulation available, but samples from the two components, relevant and irrelevant, can be drawn. Then it is possible to look -- by the mode of communication -- at the relationships between these components.

If the various communication situations which appear to provide greater focusing do in fact screen out or de-emphasize irrelevancies, it should be expected that the differences between proportions of relevant and irrelevant learning should emerge in the following order:

Communication Situation	Degree of Focusing	Rank Order of "Channel Effectiveness"
Natural Laboratory	Minimal	4
Laboratory plus short film	Some focusing	3
Film substitute for laboratory	Sharp focusing	2
TV reproduction of film	Maximum focusing	1

2. RESEARCH PROGRAM

2.1. Film Preparation

Fourteen colored sound films of various laboratory experiments were prepared. These films were used both to supplement the work done in the laboratory and to replace it. The replacement of the traditional laboratory instruction in the Strength of Materials course by the films made it possible to teach an increased number of students at no additional cost. It also made available the existing laboratory equipment for research purposes by the increasing number of graduate students.

The titles of the film produced, as well as the running time of each is given below:

Title	Length
1. Calibration Experiment	29 minutes
2. Tension	21 minutes
3. Torsion Experiment	21 minutes

4.	Strain Distribution in Beams	22 minutes
5.	Horizontal Shear	25 minutes
6.	Creep and Relaxation	20 minutes
7.	Fatigue	20 minutes
8.	Statically Indeterminate Tube Experiment	15 minutes
9.	Stress Distribution Under Eccentric Load	19 minutes
10.	Slender Column	17 minutes
11.	Beam Deflection	18 minutes
12.	Combined Stress	14 minutes
13.	Compression	17 minutes
14.	Statically Indeterminate Beam	15 minutes

The use of films in junior colleges or other institutions which cannot justify the expense of maintaining a Strength of Materials laboratory for a small volume of instruction, would make it possible for these institutions to offer satisfactory laboratory courses in the subject. Even with increased enrollments it may be difficult to justify the expense of many large items of specialized equipment for routine laboratory instruction, if it can be done satisfactorily by film.

The conditions under which the Strength of Materials course was presented included:

(a) Conventional laboratory

(b) Laboratory augmented by short color films

(c) Color films completely replacing the laboratory

(d) Films shown on closed-circuit TV giving black and white images

Learning from the individual films in the series was tested in the conventional fashion, in relation to problem solving, and in line with the suggestions concerning relevant-irrelevant classification of data. In addition, the full series was tested several terms thus permitting examination of differential effects under the several conditions.

2.1.1. Production of the Applied Mechanics Laboratory Films

The script for the films was written by various faculty members in the Applied Mechanics department. The scripts were based upon the traditional laboratory experiments, but usually enriched by supplementary material coordinating the theoretical material presented in class with the laboratory experience.

Upon completion of the script, it was reviewed by the production group, and the description of each scene and the materials and equipment needed for the scene were added. The filming was conducted in the

Applied Mechanics Laboratory in normal light using a day-light type film.

Each scene was identified by writing the number of the film and of the scene on a paper pad with a grease pencil, and shooting a few close-up frames of the pad before filming the scene. In some cases the script reader would read the commentary along as the scene was being filmed so that the actor could time his movements to fit the script. In other cases it was more convenient to make a generous estimate of the time required, and to adjust it by appropriate cutting of the film. Scenes were often shot in several versions, viewed, and a final selection made.

The drawings, charts, data sheets, and art work were made under the producer's direction, and photographed on an animation stand. The film was professionally processed and an additional light-color work print was made. Ink edge numbers were inserted on both the original and the work print.

The work print was viewed as soon as it was received and inadequate scenes were marked and designated for re-take. Upon availability of most of the scenes, choices were made between alternate versions of scenes. They were then spliced together in the correct order, with short strips of white leader inserted to indicate the position of any missing scenes. The movies were then viewed by the whole crew, with the simultaneous reading of the commentary, and final improvements were suggested.

When all scenes were in place, the final film editing was started. Scene numbers, light frames, and unnecessary sections were removed. The original commentary was often shortened and in many cases clarified. Final editing of the work print was carried out so that the length of the scenes and the commentary agreed. Upon approval of the completed movie by everyone concerned, the original film was edited to match the work print. It was then used to make a release print with a magnetic strip.

A professional radio announcer, aided by the producer who gave the necessary cues read the script. The commentary was recorded directly on the release print. The time involved for the production of a single film ranged between three and six months, depending on the number of re-takes which were necessary. Usually three different films were in various stages of production at a given time.

2.2. Relevant-Irrelevant Learning

2.2.1. Hypotheses

Three statistical hypotheses were tested in the Fall 1960 and Winter 1961 quarters:

(1) No significant difference between Film and Lab groups on their scores on the relevant test items. ($R_f = R_L$)

(2) A significant difference between groups in the scores on the irrelevant test items, with subjects in the Laboratory condition obtaining significantly higher scores than subjects in the Film condition. ($R_F < R_L$)

(3) A significant difference between groups in the "channel efficiency" index scores, with subjects in the Film condition obtaining significantly higher index scores than subjects in the Laboratory condition. ($R_F - I_F > R_L - I_L$)

(R and I stand for relevant and irrelevant test scores and the subscripts F and L stand for Film and Lab groups respectively.)

The first hypothesis stemmed from the evidence cited earlier from research involving comparison of Film or TV with traditional teaching methods. This research, by-and-large, indicates no significant differences that can be attributed to the different methods. Hypothesis 1 is based on the assumption that this study is no different from the other studies.

Earlier in this report it was stated that the following were assumed: (1) that there are more irrelevant stimuli in the "natural" laboratory than in a mass media situation; and that, furthermore, (2) irrelevant stimuli are intensified to a greater extent in the laboratory than in a mass media situation. This study dealt only with those irrelevancies common to both situations. Therefore, only the intensification assumption is pertinent to Hypothesis 2.

The third hypothesis may be derived from the first two by simple subtraction. However, it is primarily based on an assumption that the mass media situation will provide proportionately more focusing upon the relevant items of the message vis-a-vis the irrelevant items than does the "natural" laboratory situation. This relationship may hold even though one or both of the prior hypotheses is unacceptable.

The hypotheses tested during the Spring quarter, 1961, followed from the three cited above, but in this case it was possible to test all four conditions. It was predicted that the most efficient communication situation in terms of channel efficiency was the TV reproduction of the

film, followed by film only, laboratory plus film, and finally the natural laboratory which would be the least efficient.

2.2.2. Testing Program

The first testing was conducted during the winter and spring quarter of 1960. Pre-test data pertaining to the relevant and irrelevant material was gathered on 118 subjects. During these two terms the films, tests, and testing procedures were revised and improved.

This portion of the report is concerned first with the data collected during the fall quarter of 1960 and the winter quarter of 1961, and secondly, with the data collected during the spring quarter of 1961. Due to the small enrollment during the first period (Fall, 1960 and Winter, 1961) two sections were assigned to the film only condition, and two sections had the lab only. The enrollment during the spring quarter of 1961 rose to 74 students, and it was possible to test all four conditions.

The following table gives the number of students in each section, the instructor concerned, and the conditions to which the students were assigned for each of the terms covered in this section of the report.

TABLE 1

INSTRUCTORS, NUMBER OF STUDENTS, AND CONDITIONS IN STRENGTH OF MATERIALS

Term	No. of Students	Instructor	Conditions
Winter '60			
A.M. 315 Sec. 1	19	Efron	TV
A.M. 315 Sec. 2	12	Engle	Film
A.M. 316 Sec. 1	7	Bradley	Lab + Film
A.M. 316 Sec. 2	6	Schall	Lab
	43		
Spring '60			
A.M. 315 Sec. 1	7	Cooper	Lab + Film
A.M. 315 Sec. 2	16	Harris	Film
A.M. 315 Sec. 3	21	Pisacane	TV
A.M. 316 Sec. 1	17	Bradley	Lab
A.M. 316 Sec. 2	14	Engle	Lab + Film
	75		
Fall '60			
A.M. 215 Sec. 1	8	Engle	Film
A.M. 215 Sec. 2	10	Engle	Film
A.M. 216 Sec. 1	11	Schall	Lab
A.M. 216 Sec. 2	8	Efron	Lab
	37		

Table 1 (continued)

Winter '61			
A. M. 215 Sec. 1	9	Engle	Lab
A. M. 215 Sec. 2	14	Engle	Film
A. M. 216 Sec. 1	15	Schall	Film
	38		
Spring '61			
A. M. 215 Sec. 1	13	Bradley	Lab + Film
A. M. 215 Sec. 3	29	Bradley	TV
A. M. 216 Sec. 2	21	Engle	Film
A. M. 216 Sec. 3	11	Schmaltz	Lab
	74		

Six films were available for testing purposes for both the fall and winter terms. During the fall term verbal learning tests for relevant material were administered during all six different laboratory sessions. Irrelevant tests were administered only in two sessions - the first and last. In the winter experiment, both relevant and irrelevant tests were administered during the first four sessions. The testing conducted up to Winter, 1961 is summarized in Table 2. Sample test questions are shown in Appendix A.

TABLE 2

TESTS AVAILABLE FOR ALL CONDITIONS FOR FOUR TERMS

Term	Tests Available										
	R_1	I_1	R_2	I_2	R_3	I_3	R_4	I_4	R_5	R_6	I_6
Winter '60	X	X	X								
Spring '60	X	X	X	X	X		X				
Fall '60	X	X	X		X		X		X	X	X
Winter '61	X	X	X	X	X	X	X	X			

Key:

R = Relevant learning tests

I = Irrelevant learning tests

Subscript indicates number of test sessions which were as follows:

Test A	Topic
1.	Instrument Calibration
2.	Tension
3.	Torsion

4. Strain Distribution in Beams
5. Creep and Relaxation
6. Statically Indeterminate Tubes

2.2.3. Data Gathering Procedures

Since the laboratories were part of a regular course, students were permitted to choose the laboratory which best fitted their individual schedules. Students were not assigned to conditions at random.

Students in the film condition viewed the film at the beginning of their two-hour period. They were allowed to ask the instructor questions about the film, and then were given about 20 minutes to answer the quiz. Students in the laboratory section conducted an experiment, usually in groups of three, and then answered the quiz in a separate room. The latter precaution was especially necessary when the irrelevant questions were asked since the students could gain information by looking about the room.

2.2.4. Data Processing Procedures

The same criteria were used for both the irrelevant and the relevant test items. First, the items referred only to information common to both conditions. Second, an item analysis was performed. Only questions answered correctly by between 10 and 90 percent of the subjects and which had an "r" (biserial) with the total score of more than .40 were included in the final analysis. A relevant and an irrelevant score percentage correct was computed for each subject by dividing the number correct by the number of items (relevant or irrelevant) in the test.

In addition, a "channel efficiency" index was computed by subtracting from the relevant percent correct, the irrelevant percent correct (% relevant - % irrelevant). This index has the following properties:

(a) a range of +100 to -100

(b) a positive sign when the relevant percent correct is greater than the irrelevant percent correct; a negative sign when the reverse is true; and zero when the relevant percent correct equals the irrelevant percent correct.

2.2.5. Data Analysis Procedures

Analysis of variance and designed comparison procedures recommended by Snedecor and a multivariate analogue of analysis of variance recommended by Greenhouse and Geisser were used. The traditional .05 level was accepted as the dividing point between non-significant and significant results.

2.2.6. Results

2.2.6.1. Relevant Tests Scores

Table 3 presents the multivariate analysis of variance results for six tests of relevant learning for the Fall quarter 1960 and four tests for the Winter quarter 1961. The statistical hypothesis of no significant difference in relevant learning was only partially supported. While there were no significant overall differences attributable to the film versus laboratory comparison, the groups-by-tests interaction term is significant for both terms. The means listed in Table 4 indicate that on tests 1 (Instrument Calibration) and 3 (Torsion) the Film groups obtained higher scores than did the Lab groups. The reverse was true for test 5 (Creep and Relaxation). Thus for the overall test the reversals apparently cancelled each other and resulted in the traditional "no significant difference" between teaching methods.

TABLE 3

ANALYSIS OF VARIANCE RESULTS FOR RELEVANT TEST SCORES

Source	F	Significance Level
Fall, 1960		
Tests	13.57	.001
Film versus Lab	1.11	N.S.
Interaction	2.52	.01
Winter, 1961		
Tests	9.78	.001
Film versus Lab	2.35	N.S.
Interaction	5.14	.001

Notes

The above analysis computed in a manner recommended by Greenhouse and Geisser with the Film versus Lab comparison computed in a manner recommended by Snedecor for planned comparison. The sum of squares associated with "Ind x Tests" is used as the error term for testing "Tests" and "Groups x Tests"; while the sum of squares associated with "Individuals" is used as the error term for testing "Groups" and "Film versus Lab."

TABLE 4

Table of Means for Film and Lab Groups on Six Relevant Tests

Groups	Tests 1	2	3	4	5	6	Group Totals
Film Group A	79.625	68.750	69.750	28.625	49.875	57.125	58.958
Film Group B	70.500	69.375	61.625	33.875	53.500	48.500	56.229
(A + B	75.063	69.063	65.688	31.250	51.688	52.813	57.5938)
Lab Group C	56.000	69.375	35.000	35.750	57.000	50.000	50.520
Lab Group D	48.1250	80.000	42.750	43.000	73.125	44.250	55.208
(C + D	52.063	74.688	38.875	39.375	36.563	47.125	52.865)
Test Totals:	63.562	71.875	52.281	35.312	58.375	49.968	55.229

Notes:

No. of subjects per group = 8; number of groups = 4; number of tests = 6.

2.2.6.2. Irrelevant Test Scores

Irrelevant tests were administered only during the first and sixth sessions of the Fall quarter 1960, but during four sessions of the Winter quarter 1961. The predicted significant difference between the film and laboratory groups was not found in either term. Again the groups by-tests interaction term was significant (see Table 5). As indicated in Table 4, the Film groups learned more irrelevant material during the first sessions, but less irrelevant material in the sixth session than did the Lab groups.

TABLE 5

Analysis of Variance Results for Irrelevant Test Scores

Source	F	Significance Level
Fall, 1960		
Tests	16.29	.001
Film versus Lab	2.42	N.S.
Interaction	3.68	.05
Winter, 1961		
Tests	28.15	.001
Film versus Lab	2.59	N.S.
Interaction	4.19	.01

TABLE 6

Table of Means for Film and Lab Groups on Two Irrelevant Tests

Groups	Tests 1	6	Group Totals
Film Group A	37.2500	41.0000	39.1250
Film Group B	47.1250	50.1250	48.6250
(A + B	42.1875	45.5625	43.8750)
Lab Group C	31.7500	57.0000	44.3750
Lab Group D	40.0000	74.8750	57.4375
(C + D	35.8750	65.9375	50.9062)
Test Totals:	39.0312	55.7500	47.3906

Notes:

No. of subjects per group = 8; number of groups = 4; number of tests = 2.

2.2.6.3. Channel Efficiency Scores

Efficiency in learning was defined as the discrepancy between the amount of relevant information and the amount of irrelevant information a student learned. The channel efficiency index was computed by subtracting the irrelevant percent correct from the relevant percent correct. This hypothesis was examined during three terms of testing. The first two--Fall term 1960, and Winter term 1961, were concerned with only two conditions, film only and laboratory only. The third term, Spring 1961, involved all four conditions -- Lab, Lab plus Film, Film, and TV. The results of the testing for the first two terms are summarized in Table 7.

TABLE 7

Analysis of Variance Results for "Channel Efficiency" Scores

Source	F	Significance Level
Fall, 1960		
Tests	78.83	.001
Film versus Lab	10.88	.01
Interaction	0.84	N.S.
Winter, 1961		
Tests	30.52	.001
Film versus Lab	8.06	.01
Interaction	6.77	.001

Table 7 indicates that, as predicted, the Film versus Lab comparisons were significant in both terms. Again, as predicted, the Film groups obtained higher mean socres than the Lab groups. This is illustrated in Table 9. However, a significant interaction effect was found in the second term.

TABLE 8

Means and Analysis of Variance Results for "Channel Efficiency" Scores
Spring 1961

	Tests				
Groups	1	2	3	4	Group Means
Lab	9.80	13.00	-19.10	-27.30	- 5.90
Lab and Film	27.00	34.30	2.60	8.70	13.80
Film	37.00	24.80	22.60	4.35	20.01
TV	40.40	23.00	33.12	6.60	25.78
Test Means	32.58	23.75	17.15	- 4.34	17.29

Analysis of Variance Results

Source	F	Significance Level
Tests	38.96	.001
Groups	16.15	.001
Groups x Tests	2.85	.01

The F test results in Table 8 again show a significant difference between groups, and again a significant interaction. A Duncan range test was performed on the group means for all four tests, and it indicated that all except two comparisons were significant. The only non-significant results were found in the comparisons of television versus film, and in film versus film plus laboratory.

TABLE 9

Table of Means for Film and Lab Groups on "Channel Efficiency" Scores

Groups	Tests 1	6	Group Totals
Film Group A	42.3750	16.1250	29.2500
Film Group B	23.3750	- 1.6250	10.8750
(A + B	35.1250	7.2500	20.0625)
Lab Group C	24.2500	- 7.0000	8.6250
Lab Group D	8.1250	-30.6250	-11.2500
(C + D	16.1875	-18.8125	- 2.6250)
Test Totals	24.5312	- 5.7812	9.3750

Notes:

No. of subjects per group = 8; number of groups = 4; number of tests = 2.

The data, therefore, provide a degree of support for the main hypothesis. The hypothesized rank order was obtained, but not all of the difference between group means were found to be significant. In all three terms of testing, the film was found to be superior to the natural laboratory. The data for the spring term also indicated that the film condition was superior to the laboratory plus film, and that the TV condition was amore efficient mode of communication than either Laboratory plus film, or laboratory only.

These results can be interpreted as providing clear-cut evidence for the hypothesized greater efficiency of mass media over non-mass media of communication, but do not provide conclusive evidence for the hypothesized difference between the two mass media.

2.2.7. Discussion

The results of the three terms of testing are in line with, but do not completely support the statistical hypotheses. The statistical tests of Hypothesis 3 seem to indicate that it can be accepted. Since Hypothesis 3 is mathematically derivable from Hypotheses 1 and 2, and in order to have full confidence in the test of this hypothesis, it is necessary to be able to infer the acceptability of Hypotheses 1 and 2. This cannot be done.

On the other hand, the key dependent variable is the inter-relationship between the measures of two kinds of learning, relevant and irrelevant. One may have, and in fact in these data, do have, considerable variation in apparent levels of both kinds of learning from test to test. Despite this

variation, there was a consistent inter-relationship between them.

Further, the channel capacity notion, which led to the formulation of the study considers the individual to have a capacity for the receipt and recording (learning) of information. He is seen to have some volition in his utilization of that capacity between and among parts of a total message of stimulus which can be broken down into what we have called relevant and irrelevant.

It has been assumed further that the message offers information sufficient to exceed that capacity. Thus if by volition (or by some other means) he attends more to one class of stimulus than to the other, he will do so at the expense of the other.

One of the potential other means of focusing the individual upon one or the other part of the total stimulation, is the mode of communication. It has been argued that the film (and the TV) mode of communication by their very natures produce greater focusing upon relevant than upon irrelevant. This is, however, conceived of as a subtle force which does not produce effects of great magnitude. If the effects were large, of course, the differences could be determined between film (or TV) and face-to-face teaching by a simple test of relevant material. Traditionally, it has not been possible to do so at this level.

While it is true that Hypothesis 3 is mathematically derivable from Hypotheses 1 and 2, the following situation can be imagined:

The existence of small (but real) differences between a mode such as film or TV versus a mode such as face-to-face, attempts to measure such differences with relatively crude and unreliable tests, and small numbers of subjects.

Under such conditions, one should expect ordinarily to be unable to reject the null hypothesis, since the combination of small but real differences, error of measurement from unreliability, and small "n" would all tend to minimize the possibility of statistically significant outcomes. These conditions exist rather markedly for both Hypothesis 1 and Hypothesis 2, and especially for the latter.

For Hypothesis 1 the tests were of somewhat greater demonstrated reliability (and also of somewhat greater length). Further, there were six tests of the hypothesis over the same group of subjects. Even so, in total the usual Film or TV versus face-to-face results were found to be of no significant difference with regard to the method of presentation of the learning material.

2. 3. Problem Solving Ability

Section 2. 2 presents the findings of the investigation of learning of relevant and irrelevant material. The general purpose of the third year of the study was to compare student achievement in the traditional laboratory environment with those of three teaching patterns making use of a series of color films.

2. 3. 1. Hypotheses

The statistical hypothesis tested in the Spring term 1962 was that there will be no difference between treatment groups in their scores on the problem solving task.

The research hypothesis then stated that:

There will be a difference between treatment groups in their scores on the problem solving task.

2. 3. 2. Testing Program

The testing during the Fall 1961, Winter 1962, and Spring 1962 terms was devoted to the problem solving hypothesis. The original project proposal stated:

Problem solving tests will show the effects of directness of experience, with the normal laboratory giving the best performance, followed by the other three conditions.

The enrollment during the Fall and Winter terms is always quite small, and it was decided to pre-test the measuring instrument using two sections, film only and lab only. It was anticipated that all four conditions would be tested in the Spring term, but due to low enrollment, the closed-circuit television section had to be eliminated.

The questions used to test problem solving ability required the students to use the knowledge obtained from their laboratory experience to design new experiments, to select the equipment they would use, to set up the experimental apparatus, and to state the measurements they would take. All of the questions required the students to extrapolate beyond the material with which they were already familiar. A sample examination is included in Appendix B.

Table 10 shows the number of students, the instructors, and the conditions assigned during each of the three quarters. A sufficient number of films had been completed so that the film and also the Film plus Lab sections were able to view a film each week of the term. In the latter section the students viewed the film and then came to the laboratory and performed the experiment. The extra instruction obtained from viewing

the film enabled this section to complete laboratory assignments in the same length of time that it took the laboratory only section.

TABLE 10

Instructors, Number of Students, Conditions in Applied Mechanics Classes

Term	No. of Students	Instructor	Condition
Fall '61			
A.M. 215, Sec. 1	12	Efron	Film
A.M. 216, Sec. 1	18	Tatro	Lab
Winter '62			
A.M. 215, Sec. 1	11	Bradley	Lab
A.M. 215, Sec. 2	10	Tatro	Lab
A.M. 216, Sec. 1	13	Efron	Film
Spring '62			
A.M. 215, Sec. 1	19	Engle	Film
A.M. 215, Sec. 2	22	Lasker	Lab
A.M. 216, Sec. 2	24	Efron	Film + Lab

2.3.3. Data Gathering Procedures

The laboratories were part of a regular course, and so students had to be permitted to choose the laboratory which best fitted their individual schedules. Random assignment to conditions was not possible, but it was felt from some previous testing that there were no significant differences in ability between students in the three conditions.

The problem solving test was given during the last two-hour laboratory period of the term to all sections. The students were allowed to use the full two hours. They were told that their grade would contribute to the course grade. The questions for all sections were graded by Dr. Charles O. Harris.

2.3.4. Data Analysis Procedures

Ten questions on problem solving were tested during the Fall term 1961 and ten different questions during the Winter term 1962. An item analysis was performed on all questions. Only those questions answered correctly by between 10 and 90 percent of the subjects and which had an "r"

(biserial) with the total score of more than .57 were included in the final form used during the Spring term. Five questions were selected from both the Fall 1961 and Winter term 1961. Consideration was also given to the subject matter of the questions, so that they would cover as many of the laboratory experiments as possible. The biserial scores for the Fall, Winter, and Spring terms 1961-1962 are given in Table 11.

TABLE 11

Biserial Analysis for Fall '61, Winter '62, and Spring '62 Terms

Fall 1961

Item	1	2*	3*	4*	5	6	7	8	9*	10*
r-Biserial	.04	.63	.63	.57	.63	.30	.14	.42	.84	.65

Winter 1962

Item	1	2	3	4*	5*	6*	7	8*	9*	10
r-Biserial	.09	.57	.52	.76	.62	.79	.58	.72	.73	.27

Spring 1962

Item	1	2	3	4	5	6	7	8	9	10
r-Biserial	.53	.58	.93	.53	.64	.56	.42	.57	.42	.48

* Questions selected for Spring '62 Problem Set

The biserial analysis on the rate scores for the Spring term 1962 yielded rather low scores for questions number 7, 9, and 10. It was decided to use a purified score for the remainder of the analysis. The raw scores are given in Table 12.

TABLE 12

Problem Solving Scores for Three Groups - Spring 1962

Purified Scores (Maximum Grade = 70)

Student No.	Film	Lab	Film plus Lab
1	20	27	64
2	33	47	33
3	43	13	27
4	36	27	70
5	40	60	47
6	67	50	47
7	24	34	50
8	40	34	53

Table 12 (continued)

Student No.	Film	Lab	Film plus Lab
9	60	70	63
10	54	33	67
11	37	39	46
12	60	44	57
13	56	36	46
14	37	57	57
15	57	36	60
16	41	57	57
17	33	41	60
18	31	53	50
19	47	60	19
20	-	37	44
21	-	20	53
22	-	63	70
23	-	-	47
24	-	-	61

The mean scores for the three sections are shown in Table 13.

Table 13

Mean Scores and Variance for Spring 1962

Condition	No. of s's	Mean Scores	Variance
Film	19	42.9	168.5
Laboratory	22	42.6	220.0
Film + Lab	24	52.0	161.7

The Film plus Laboratory group had the highest score, while the other two groups had almost the same values. There appeared to be a greater degree of variance in the laboratory group.

2.3.5. Results

Analysis of variance of the simple randomized design was used. The traditional .05 level was accepted as the dividing point between non-significant and significant results. Table 14 summarizes the results of the analysis of variance using the purified scores (total scores minus those on numbers 7, 9, and 10). The F-value obtained is significant at the .05 level.

TABLE 14

Analysis of Variance with Purified Scores

Source of Variation	df	Mean Square	F
Between Treatments	2	643.87	3.51*
Within Groups	62	183.39	
Total	64		

* significant at .05

The data was then analyzed using the Bartlett test of homogeneity of variance. It was ascertained that the treatment group variances were not significantly different. Under this assumption of homogeneity of the variance, an individual comparison of the largest and smallest means was calculated using the t-test and studentized range distribution. This comparison was between Laboratory-only and Film plus Laboratory, but yielded no significant difference.

The analysis of variance indicated significant differences among the treatment scores, showing that the method of instruction did have an effect upon the problem solving ability of the students. The next question which might be ask is whether these differences could have been caused by variations in the students' ability to deal with this particular course material. In order to answer this question an analysis of covariance was carried out, using the course grades and the purified problem solving scores. The results are summarized in Table 15.

TABLE 15

Analysis of Covariance and Test of Significance of Adjusted Groups Means

Source of Variation	df	Sums of Squares and Products			Errors of Estimate	
		S_x^2	S_{xy}	S_y^2	df	Mean S
Between Treatments	2	1.1	- 7.5	1,287.7		
Within Groups	62	71.0	492.0	11,370.0	61	130.5
To test of significance of adjusted means					2.	720.6**
Total	64	72.1	484.5	12,657.7	63	

F = 5.53**

** significant at .01

The F-value was found to be highly significant. Thus scores on the problem solving test could not be explained solely by differences in ability of the students as demonstrated by their grades in the Strength of Materials course. Even after the problem solving scores have been adjusted to a common basis, they differ significantly. In other words, score differences in the problem solving test must be at least partly ascribed to differences in the effectiveness of the method of instruction.

Having found significant difference among the treatments in the analysis of variance, and having shown that students' ability could not account for this difference, the data was further analyzed by the Duncan Multiple Range test. The results show that there is no difference between film only and laboratory only methods of instruction. The combined Film plus Laboratory method did, however, differ significantly from the film only and laboratory only methods. Results are presented in Table 16.

TABLE 16

Duncan Multiple Range Analysis of Purified Problem Solving Scores

Group	Mean	$s_m = 2.887$
Film	42.947	
Lab	42.636	$R_2 = 8.167$
Film + Lab	52.000	$R_3 = 8.592$

	Lab	Film	Film + Lab
Lab		0.311	9.364*
Film			9.053*
Film + Lab			

* significant at .05

2.3.6. Discussion

This part of the research project, the teaching of a Strength of Materials course by the use of films, was specifically concerned with the problem solving aspect. It is important that students be able to extrapolate from the material presented to them in order to solve new problems, in terms of designing the experiments, and specifying the apparatus to be used and the measurements to be taken.

The analysis showed a significant difference among the various presentation methods. The combined Film plus Laboratory far outdid

the film only and laboratory only methods, in terms of the scores obtained on a standard test by the students exposed to those different methods of presentation. This was to be expected, since the student is able to benefit from the systematic, detailed, very complete presentation on film, as well as from the exposure to the apparatus available to him in the Applied Mechanics laboratory.

The comparison of the Film only and the Laboratory only methods yielded the verdict of no significant difference. This is to say that a student will learn as much from a film presentation of the Strength of Materials coursework as he would from being exposed to the natural laboratory. This finding is especially significant in terms of the application of films such as these in junior colleges and other institutions that cannot possibly afford the expensive equipment.

Since the analysis was carried out on one term's work by three relatively small classes, it was felt that the better students might have fallen into one section rather than the others. This possibility was quite high, since there was no way to randomly assign students to the different classes. Therefore, further analysis was carried out holding aside "ability to deal with this specific coursework," defined as the instructors' grades for the students. In so doing, the analysis showed that even when the student's general ability with the Strength of Materials work was taken into account, there was a significant difference. Therefore, it was concluded that this difference must be at least partly attributable to the different methods of presentation.

An observation which was made over the testing period for the 1961-1962 academic year indicated that the students receiving the Film plus Laboratory method of instruction carried out the experiments in a more purposeful manner. This is to say, it was noted that, after having seen the film concerning the laboratory experiment to be conducted, the students could go into the laboratory and complete the experiment, as well as take a short test on what had been done, in the same 2-hour period that the laboratory only class spent doing the experiment. This generalization depended upon the length of time each experiment took. This economy of students' time and effort, as well as the clearer thinking and directionality of both students and professor, is an encouraging justification for the use use of films in the teaching of Strength of Materials and other laboratory courses.

Suggestions for future research along these lines include the possibility of dealing with coursework in other fields of study. Again, study which involves expensive or scarce apparatus or materials, may warrant the use of filmed laboratories. Much tighter experimental control is necessary, and perhaps in other institutions or in other fields of education, this may be possible. It has also become apparent that there may be differential effects upon learning by the various methods of presentation, depending upon the subject matter of the material presented. This aspect was not tested in this study, and it could contribute a great deal in terms of which individual laboratories are worth putting on film from the viewpoint of justifying their expense.

3. . APPENDICES

3. 1. . Appendix A

Sample Examination for Relevant-Irrelevant Hypotheses

1. The standard blocks which you have used in this experiment are accurate to: (check one) 2/1,000" ___ 2/10,000" ___ 2/100,000" ___ 2/1,000,000" ___

2. You are going to calibrate an Ames Gage against a set of blocks. Check which of the following statements are true and which are false.

	True	False
(a) Mount the dial gage firmly on a clamp stand	____	____
(b) Adjust it so that the spindle is vertical	____	____
(c) Tap the dial gage lightly with your finger	____	____
(d) Take a zero reading without blocks	____	____
(e) Take several readings using different block combinations	____	____
(f) Stack the gage blocks lightly on top of each other	____	____

What should the final measurement consist of in this experiment?

3. How many digits should you read for:
   (a) The Ames Dial gage
   (b) The Metzger Strain gage
   (c) The SR-4 Strain gage
4. What mechanism is used as the multiplying device of the Metzger strain gage?
5. What 2 quantities do you need to know about the Metzger strain gage to be able to calculate strains from the gage readings?
6. What is the function of the compensating gage in the SR-4 bridge circuit?

We are interested in finding out about all the things you have noticed in this laboratory. Please try and answer each of the following questions, even when you are not certain of the answers.

1. Where is the Ames Gage manufactured?

   Philadelphia, Pa. ____
   Pittsburgh, Pa. ____
   New York, N. Y. ____
   Waltham, Mass. ____
   None of the above ____

2. What material is the cantilever beam made of ?

   Aluminum ____
   Steel ____
   Magnesium ____
   None of these ____

3. How many blocks were there in the box?

4. Who is the Metzger strain gage made by?

   (a) F. B. Metzger ____
   (b) F. L. Metzger, Ltd. ____
   (c) F. F. Metzer and Son ____
   (d) B. L. Metzger and Co. ____
   (e) None of these ____

5. Check the position of the gage factor dial on the static indicator.

   Top left ____
   Top right ____
   Bottom left ____
   Bottom right ____
   Center ____

6. How many complete circles of numerals are there on the faces of the following gages?

   The Ames Gage ____
   The Metzger Gage ____

7. Are there any holes in the face-plate of the Metzger gage? If so, how many?

8. Is the gage factor dial of the static indicator a circle or a spiral?
   Circle ____
   Spiral ____

9. How many straining frames are there in the lab?
   Number ____

3. 2. Appendix B

Sample Examination for Problem-Solving
(Given in Spring, 1962)

General Instructions

For those questions which involve design of an experiment, you may consider all of the resources of the laboratory at your disposal; i.e., apparatus, instruments, bars cut to the specified length, drilled, tapped, etc. Answers should include a properly labeled sketch of the equipment used, the measurements to be taken, and how these measurements are to be used in determining the final result. Be complete, but brief.

Questions

1. How would you proceed to determine the location of the neutral axis of a beam from strain measurements at the top and bottom surfaces?
2. Indicate how you would load a beam so as to have a 40" length in which the shear force is 80 lb.
3. A wire of low strength material is to be loaded in tension by a dead weight of 100 lb. The wire is approximately 30" long before loading. The test is to be so arranged that the 100 lb. weight reaches a supporting platform after the wire has stretched 1", after which the length of wire is not to increase more than 0.01". How would you measure the tensile force in the wire during the 10 minutes immediately after the weight touches the platform?
4. A circular rod is to be loaded in tension, and it is anticipated that there will be some eccentricity of the load. What is the MINIMUM number of SR-4 strain gages which can be placed on the bar, so that the eccentricity of the load can be calculated from measured strains?
5. In the process of developing the slender column experiment, it was found that the buckling load of a certain bar was greater than the capacity of the system. The decision had already been made that the load capacity of the system was not to be increased, so a new test bar had to be selected. What changes can be made (and what is the effect of each) in the characteristics of the bars in selecting a new bar which has a buckling load within the capacity of the system?

6.

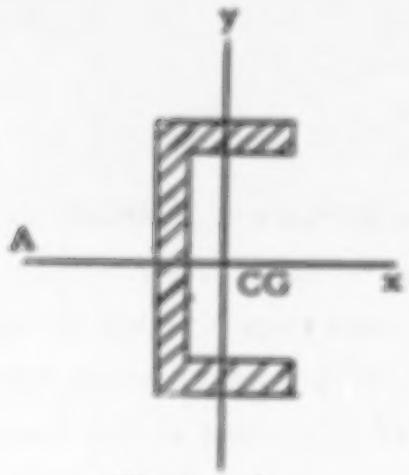

Figure 1

If the cross section of a beam has only one axis of symmetry, as shown in Fig. 1, the beam will twist when subjected to vertical loads unless the plane of the loads passes through the "shear center" A. How would you set up an experiment to locate A?

7.

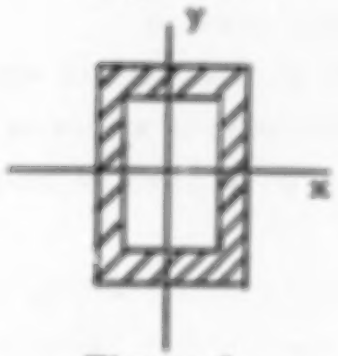

Figure 2

If the beam cross section of Fig. 2 is tilted slightly and the beam is subjected to vertical loads, there will be bending about the y-axis as well as about the x-axis. How could you determine the bending moment about the y-axis in an experiment?

8. How would you know when to stop taking measurements of force in a tension relaxation experiment?

9. A certain mechanical strain gage (Metzger) has a 2" gage length, lever ratio of 10, and each dial division represents a spindle travel of 0.001". It is attached to a tension specimen, the stressed portion of which is 6" long and of constant cross section. What is the speed of the moving cross head of the testing machine when the angular velocity of the dial gage pointer is 0.5 radians per second?

10. The angle of twist is to be measured for a torque of a certain magnitude, which is to be applied to a series of solid circular bars of the same material but of different diameters. How do you pick up gage length of the troptometer so that the probable per cent of error is the same for all bars?

3. 3. Appendix C

Combined Stress No. 12

Today we are going to perform an experiment in which we study the state of stress at a point. We are going to subject a circular magnesium alloy tube to combined torsion and flexure, and measure the principal strains. Then we will calculate the principal stresses and go on to calculate the modulus of elasticity and Poisson's ratio of the material.

Torsion is twist. When a circular bar is subjected to a torque, T, a shear stress, tau, is developed on each cross section.

The maximum shear stress occurs at the surface and is equal to the torque, T, times the radius, a, divided by the polar moment of inertia, J. Shear stresses of the same magnitude are developed on longitudinal planes.

Flexure is bending. When a bar is subjected to a bending moment, M, a normal stress, sigma, is developed on each cross section. The maximum normal stress occurs at the top of the cross section and is equal to the bending moment, M, times the radius, a, divided by the moment of inertia, I.

The stresses calculated from the torsion and flexure formulas are on transverse and longitudinal planes, as shown in this view looking downward to an element on the top surface of the bar. However, these stresses may not be the most significant stresses in the bar.

The maximum and minimum normal stresses are called principal stresses. They occur on oblique planes, which are called principal planes, and on which there are no shear stresses. The magnitudes of the principal stresses are calculated from this formula, in which the plus sign is used for sigma one, and the minus sign for sigma two.

The directions of the principal planes are calculated from the formula; tangent two theta equals two times tau, divided by sigma.

Measurements are taken from a sample length of the tube. The outer diameter is three inches and the wall thickness is one-fourth inch.

Here are the dimensions of the cross section. The polar moment of inertia is: J equals pi over two, times a to the fourth minus b to the fourth, and is 4. 12 inches to the fourth. The rectangular moment of inertia is: I equals pi over four, times a to the fourth minus b to the fourth, and is 2. 06 inches to the fourth.

The circular tube is clamped at one end. Loads are applied at the end of an arm which is fastened to the other end of the tube.

The distance from the center of the tube to the load hanger is 24 inches. This is the moment arm for torque.

SR-4 strain gages are located on the top surface of the tube, at distances of 12-3/4 inches, 24-3/5 inches, and 36-3/4 inches from the free end of the tube. These distances are the moment arms for bending moment.

This picture shows the tube, and moment arms. At the cross section where gages 1 and 2 are located, the torque arm is 24 inches, and the bending moment arm is 12.75 inches.

The shear stress, tau, equals T times a divided by J.

In this case, tau, equals 8.74 w. The normal stress, sigma, equals M times a divided by I.

In this case, sigma, equals 9.25 w. These are the stresses on transverse and longitudinal planes at the location of gages one and two.

The principal stress, sigma one and sigma two, are calculated.

Sigma one equals 14.51 w and sigma two equals minus 5.27 w. The directions of the principal planes are given by the angle, theta.

Theta is 31.1 degrees.

The SR-4 strain gages are connected to the switching and balancing unit and the static indicator.

A temperature compensating gage is located on a short sample length of the tube, and connected into the measuring system.

The data sheet is prepared with space for the loads, the static indicator readings from the strain gages, and the strains.

Each strain gage circuit is balanced at a reading of 13,000 micro-inches per inch.

And these initial readings are recorded on the data sheet.

A load of 50 pounds is placed on the load hanger.

A strain reading is taken for each gage,

and recorded on the data sheet.

Strain readings are also taken for each gage at loads of 100 pounds, 150 pounds, and 200 pounds,

and recorded.

Remember, that the strain gages are oriented in the direction of the principal strains.

The principal strains are calculated by subtracting the initial indicator readings from the indicator readings under load.

For example, the principal strain from gage 1 at the load of 150 pounds is obtained by subtracting the initial reading of 13, 000 microinches per inch from the load reading of 12, 798 microinches per inch. This principal strain is minus 202 microinches per inch.

The principal strains are plotted against the loads. A straight line is drawn to represent the output of each gage. At each gage location, one principal strain is positive, or tensile, and the other is negative, or compressive. The largest strains are obtained from gages 5 and 6, so these strains are used to calculate the modulus of elasticity and Poisson's ratio for the material.

A calculation sheet is prepared and the loads are entered.

Next, the torque is calculated for each load, by multiplying the load by the moment arm for torque.

The values of the torque are entered on the calculation sheet.

The shear stress, tau, is calculated from the torsion formula and entered on the calculation sheet.

The bending moments at gages 5 and 6 are calculated by multiplying each load by the moment arm, 36. 75 inches.

The normal stress, sigma, is calculated from the flexure formula and entered on the calculation sheet.

The principal stresses are calculated from this equation, and entered on the calculation sheet.

Then the modulus of elasticity, E, and Poisson's ratio, mu, are calculated by using Hooke's Law, which is usually written to express the strains in terms of the stresses or, more conveniently for our purposes, as:

E equals sigma one squared/minus sigma two squared, divided by sigma one epsilon one/minus sigmas two epsilon two, and mu equals sigma two epsilon one/minus sigma one epsilon two, divided by sigma one epsilon one minus sigma two epsilon two.

For example, using the data for the 200 pound load, E is calculated as 6. 19 times 10 to the sixth pounds per square inch,

and mu is calculated as 0. 27.

The values of E and mu are entered on the calculation sheet. The values of E vary from 6. 11 times 10 to the sixth to 6. 25 times ten to the

sixth pounds per square inch, and compare well with the accepted value of 6.4 times 10 to the sixth pounds per square inch.

The values of mu vary from 0.26 to 0.27 and are quite reasonable for this metal.

In summary, you have seen an experiment in the state of stress at a point, in which a circular magnesium alloy tube:

Was subjected to combined torsion and flexure.

Principal strains were measured at the top surface of the tube at three cross sections.

The principal strains were plotted against the loads.

Principal stresses were calculated at one cross section.

The modulus of elasticity and Poisson's ratio were calculated from these principal stresses and the principal strains at the same location.